U.S. Department of Transportation
Federal Aviation Administration

Advisory Circular

Subject: INSTRUCTIONS FOR CONTINUED AIRWORTHINESS: IN-SERVICE INSPECTION OF SAFETY CRITICAL TURBINE ENGINE PARTS AT PIECE-PART OPPORTUNITY

Date: 3/8/01
Initiated By: ANE-110
AC No: 33.4-2
Change:

1. **PURPOSE**. This advisory circular (AC) provides guidance and acceptable methods, but not the only methods, that may be used to demonstrate compliance with the requirements of §33.4 of Title 14 of the Code of Federal Regulations, Instructions for Continued Airworthiness. This AC deals with instructions for in-service inspections of safety critical turbine engine parts. The need for in-service inspections is determined by a qualitative assessment of the safety implications of a cracked safety critical part. The in-service inspections should be conducted each time one of these safety critical parts is completely disassembled, unless the part has been inspected within the last 100 cycles in service.

2. **RELATED REGULATIONS**.

a. Section 33.4, Instructions for Continued Airworthiness.

b. Part 33 Appendix A, Sections A33.3(a)(6) and A33.3(b)(2), Instructions for Continued Airworthiness.

3. **RELATED REFERENCE MATERIAL**.

a. AC 33-2B, Aircraft Engine Type Certification Handbook, dated June 30, 1993.

b. AC 33.4-1, Instructions for Continued Airworthiness, dated August 27, 1999.

c. Joint FAA – Aerospace Industries Association (AIA) report, Propulsion System and Auxiliary Power Unit (APU) Related Aircraft Safety Hazards, dated October 25, 1999.

4. **DEFINITIONS**. The following terms are defined for the purpose of this AC:

a. Continued Airworthiness Assessment Methodology (CAAM) Level 3 Hazard or Event. A CAAM level 3 hazard or event is a propulsion system or auxiliary power unit (APU) malfunction that involves substantial damage to the aircraft or second unrelated system, small penetrations of aircraft fuel lines or aircraft fuel tanks, significant damage to a second engine system, uncontrolled fires, rapid cabin depressurization, permanent loss of thrust or power greater than one propulsion system, inability to climb and maintain flight at least 1000 feet above terrain, or impairment of aircraft controllability.

b. CAAM Level 4 Hazard or Event. A level 4 hazard or event is a propulsion system or APU malfunction that involves forced landing, loss of aircraft (hull loss), fatalities, or serious injuries.

c. Critical Feature. A critical feature is an attribute, characteristic, or property of a part that results in the part having relatively high stress, susceptibility to handling damage or foreign object damage (FOD), or low tolerance to material or other anomalies.

d. Damage Tolerance. Damage tolerance is an element of the turbine engine component design and life management process that accounts for potential component imperfections. Component imperfections could result from inherent material structure, material processing, component design, manufacturing or usage. Damage tolerance addresses component imperfections by incorporating appropriate combinations of fracture-resistant design, fracture mechanics, process control, and nondestructive inspection.

e. Eddy Current Inspection (ECI). ECI is a nondestructive testing method in which eddy current flow is induced in a test object. Variations in the test object cause changes in the flow that are detected by a nearby coil or a Hall effect device for subsequent analysis.

f. In-service Inspection. An in-service inspection is a detailed inspection of a specific critical feature or area of a part.

g. Fluorescent Penetrant Inspection (FPI). FPI is a surface crack detection process that uses a penetrating fluid with a fluorescent suspension to enter crack separations by capillary action. A black light is used to visually detect cracks containing this fluid.

h. Hazard Ratio. The hazard ratio is the percent of total events of a particular turbine propulsion system or APU malfunction or failure that has serious or severe consequences (i.e., hazard level 3 or 4).

i. Line-of-Sight. Line-of-sight refers to the qualitative assessment of the ability to visually inspect piece-part features. Deep holes or features that are obstructed by adjacent part features, narrow access passages, etc., are considered to have poor "line-of-sight" inspection capability.

j. Non-Destructive Inspection (NDI). An NDI is any inspection that identifies stress, strain, dimensional, crack or flaw characteristics without compromising the integrity or airworthiness of the part.

k. Piece-Part Opportunity. Piece-part opportunity is the opportunity to perform in-service inspection of safety critical parts when such parts are completely disassembled in accordance with the manufacturer's or other FAA-approved maintenance or overhaul manual instructions. Inspections are triggered by opportunity, not by a time or cyclic interval requirement.

l. Probability of Detection (POD). POD is a quantitative statistical measure of the capability to detect a particular type of anomaly (flaw) over a range of sizes using a specific NDI technique under specific conditions.

m. Safety Critical Parts. Safety critical parts are those parts of an engine whose failure is likely to directly present a CAAM level 3 or 4 hazard to the aircraft.

n. Uncontained Failure. Uncontained failure is the uncontained release of debris caused by the malfunction of an engine component (blade, disk, spacer, impeller, drum/spool, pressure vessel). In order to be categorized as uncontained for the purposes of this AC, the debris must pass completely through the nacelle. Parts or fragments that puncture the nacelle skin but do not escape or pass completely through are not considered "uncontained." Parts or fragments that pass out of the inlet or exhaust opening without passing through any structure are also not considered "uncontained."

5. **BACKGROUND**. Analysis of fifteen years of transport aircraft accident and incident data shows that the leading cause of engine related CAAM level 3 and 4 accidents for turbofan engines is the uncontained failure of safety critical parts. The failure of safety critical parts can present a significant hazard to an aircraft by releasing fragments that can penetrate the cabin or fuel tanks, damage control surfaces, or sever flammable fluid or hydraulic lines. To significantly reduce the occurrence of these incidents, part features most critical to safety should be subjected to in-service inspections at each piece-part opportunity during their service lives, using methods that detect flaws that could lead to failure.

a. In daily operation, many engine parts are exposed to high thermal and mechanical loads. As a result of these loads, cracks can form. If these cracks are not detected, they can grow and lead to part failure. Cracks can also form for many other reasons, including the following:

(1) Material impurities.

(2) Machining during manufacture or repair.

(3) Unexpected stress levels due to part design or operation.

(4) Unanticipated operating conditions.

(5) Foreign object damage.

(6) Handling damage during overhaul or repair.

(7) Corrosion.

b. As part of the certification plan, the applicant should identify the safety critical parts likely to result in a CAAM level 3 or 4 event if they fail. When these parts and their associated inspection instructions are included in the airworthiness limitations section (ALS) of the ICA required by §33.4, the inspections become mandatory operational restrictions.

c. The incorporation of damage tolerance design methods acceptable to the Administrator enables a TC holder or applicant to evaluate the vulnerability of a safety critical part to anomaly threats. Therefore, TC holders who have designed or assessed safety critical parts using a damage tolerance design methodology may establish in-service inspections based on the part's damage tolerance characteristics and analyses.

6. **CRITICAL PARTS AND FEATURES IDENTIFICATION**. Effective in-service inspections include identification of the safety critical parts, the most critical features, and the inspection processes that reliably detect flaws in these features. Each applicant should conduct an assessment to establish which parts and part features are candidates for in-service inspection.

a. Selection of Parts. The primary consideration for the selection of safety critical parts requiring in-service inspection is the consequence of failure of the part. Parts whose failure is likely to result in a CAAM level 3 or 4 event, regardless of the probability of occurrence, should be subject to in-service inspection.

(1) Methods for identifying safety critical parts should incorporate the following:

(a) Service experience of similar parts.

(b) Kinetic energy analyses of the part at operational levels.

(c) Characteristics of the surrounding containment structure.

(2) Safety critical parts should include: fan disks and hubs, high pressure turbine (HPT) disks, low pressure turbine (LPT) disks, high pressure compressor disks and drum rotors. The list may also include parts on large engines, such as cooling plates, shafts and spacers, due to their mass.

(3) If there is insufficient field experience to accurately determine the likelihood and consequence of failure, design configurations should be qualitatively evaluated using the most relevant field experience and the safety assessment conducted for certification. The qualitative assessment should include, but is not limited to, the following factors:

(a) Stress and temperature level relative to material capability.

(b) Crack growth rate.

(c) Crack path and the most critical fracture pattern.

(d) Kinetic energy of fragments of similar components that had previous CAAM level 3 and 4 events.

(e) Potential crack and damage types.

b. Feature Identification. Once the list of safety critical parts has been established, a historical review of the features that have caused the failure of similar parts should be conducted.

(1) This feature review should incorporate the following factors:

(a) Failure history.

(b) Failure root causes.

(c) Feature history.

(d) Susceptibility to handling and foreign object damage.

(e) Susceptibility to material impurities.

(f) Susceptibility to corrosion, fatigue, and creep.

(2) CAAM and mature TC holder databases have been considered acceptable for this review. The design characteristics of the part should be considered when evaluating features.

(3) When evaluating a feature for in-service inspection, the following characteristics should be included as appropriate:

(a) High stress.

(b) Residual stress (compressive or tensile).

(c) Peening effects on crack detection and growth rate.

(d) Residual life.

(e) Material characteristics.

(f) New or novel materials.

(g) Manufacturing and repair processes.

(h) Severity of operating environment (temperature, speed, corrosion, etc.).

(i) Cleaning requirements.

(4) An applicant may conduct fracture mechanics analyses to support the identification of the most critical part features.

7. **INSPECTION METHODS**. FPI and ECI are acceptable methods, but not the only methods, for crack detection. Whether FPI, ECI or another method is used, the prescribed inspection method should have a demonstrated reliability of detecting cracks on the targeted part feature and a well-developed process that minimizes variation and maximizes detection sensitivity and reliability.

a. FPI is the most widely used inspection method for detecting surface flaws in turbine engine parts. Many safety critical parts currently receive global or full field FPI inspections periodically. However, parts with poor line-of-sight features, surfaces with high residual compressive stress, rough surface finishes, complex feature details, or parts that are hard to clean are not usually appropriate candidates for FPI.

b. To raise crack detection capabilities to a higher level, other inspection techniques, such as ECI, should be considered for those features for which FPI is not considered appropriate. Typically, ECI is appropriate for disk bores, high length to diameter (L/D) ratio holes, dovetail slots, and other highly stressed features. Considerations in selecting an inspection method include, but are not limited to, desired process sensitivity and reliability, accessibility, part condition, feature geometry and POD.

8. **FREQUENCY OF INSPECTIONS**. To maximize the likelihood of crack detection, in-service inspections should be conducted at each piece-part opportunity, regardless of which inspection method is chosen. The TC holder should determine at which disassembly level the part would be sufficiently disassembled to allow for meaningful inspection. Parts that are configured with riveted, pressed-on, or otherwise attached hardware whose removal is likely to expose the part to additional damage should not necessarily be further disassembled to accommodate focused inspection.

9. **ENGINE INSTRUCTIONS FOR CONTINUED AIRWORTHINESS (ICA)**.

a. The engine manual ICA should contain language to include the in-service inspections. The ALS of the ICA should incorporate the following factors:

(1) Definition of “piece-part” or other appropriate disassembly level.

(2) Identification of the parts requiring in-service inspection.

(3) Location of the inspection instruction details.

(4) Specification of when the inspection is required.

b. TC holder ICAs are not standardized in the description of the ALS; titles such as “Chapter 5,” “Time Limits Section,” or “Lifing Service Bulletins” are used. Engines with a certification basis prior to Amendment 9 of part 33 are subject to the establishment of limitations in accordance with §33.5, Instruction manual for installing and operating the engine, which does not require a separate ALS. Engines with a certification basis of part 33 Amendment 9 and later are subject to the requirements of §33.4, Instructions for Continued Airworthiness, which does require a separate ALS.

c. The step-by-step instructions for the actual inspections should be placed in the appropriate engine overhaul manual section or other readily accessible shop document.

d. The following, or similar language, should be included in the ALS or Chapter 5 of the engine manual to assure that the in-service inspections are incorporated into the operator's continuous airworthiness maintenance plans:

AIRWORTHINESS LIMITATIONS
MANDATORY INSPECTIONS

1. Perform inspections of the following parts at each piece-part opportunity in accordance with the instructions provided in the applicable manual chapter(s):

Part Nomenclature	*Part Number (P/N)*	*Inspect per Applicable Manual Chapter*
Fan Disk	*All*	*72-31-xx-xxx, Fluorescent Penetrant Inspection* *and* *72-31-xx-xxx, Eddy Current Inspection*
HPT Rotor Interstage Seal	*All*	*72-53-xx-xxx, Fluorescent Penetrant Inspection*

2. For the purposes of these mandatory inspections, piece-part opportunity means:

a. The part is considered completely disassembled in accordance with the disassembly instructions in the engine manufacturer's maintenance manual; and

b. The part has accumulated more than 100 cycles in service since the last in-service inspection, provided that the part was not damaged or related to the cause for its removal from the engine.

e. Applicants should submit the in-service inspection ICA to the Aircraft Certification Office (ACO) responsible for overseeing that type certification project for acceptance. The ACO and an Aircraft Evaluation Group (AEG) will jointly determine the acceptability of the ICA. The AEG will review the in-service inspection ICA and make recommendations on the maintenance and operational aspects. The ACO will determine final acceptance of the completed ICA. The in-service inspection instructions may be incomplete at type certification if a program exists to ensure its completion either:

(1) Prior to delivery of the first aircraft with the engine installed; or

(2) Upon issuance of a standard certificate of airworthiness for the aircraft with the engine installed, whichever occurs later.

f. Supplemental type certificates (STCs) or parts manufacturer approvals (PMAs) that incorporate safety critical parts should contain in-service inspection ICA as part of the design approval. The STC or PMA applicant is responsible for producing, distributing and maintaining the required in-service inspection ICA.

10. **RECORD KEEPING**. Any person who performs the in-service inspection on a component or part should make an entry in the maintenance record of that component or part after inspection. Operators may incorporate the records of these inspections into existing maintenance record keeping systems.

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